REPORT OF FINDINGS

TOWN OF BRANFORD, CT
Long Island Sound

POTENTIAL SEDIMENTATION IMPACTS WHICH COULD RESULT FROM DREDGING

MP 10.9 - MP 12.0
Proposed Construction of
The Islander East Gas Transmission Pipeline

Prepared For
The Town of Branford

Revision Date: May 5, 2003

Prepared By

JOHN C. ROBERGE, P.E., LLC
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JOHN C. ROBERGE, P.E., LLC

EXECUTIVE SUMMARY

Potential sedimentation impacts which could result from construction dredging, proposed for the installation of the Islander East Gas Transmission Pipeline were evaluated by **JOHN C. ROBERGE, P.E., LLC** at the request of the Town of Branford. The proposed construction operations include dredging of approximately 51,000 cy of bottom sediments to construct a basin and pipeline trench. The project proponent originally planned to place the dredged material onto subaqueous mounds adjacent to the pipeline trench. The dredged material management methods have been altered, as reflected in documentation provided by the project proponent modifying the regulatory permit applications, to include placement of the dredged materials onto barges.

> *It was demonstrated that turbidity levels and sediment deposition, resulting from the proposed construction of the Islander East Pipeline Company, LLC natural gas pipeline, will potentially and significantly impact the adjacent waters of Long Island Sound.*

The anticipated turbidity levels and deposition will be highly dependent upon the rate of initial sediment release at the dredging position. Empirical values of sediment release rates for comparable observed dredging operations were employed to develop limits of potential suspended sediment plumes which could result from the pipeline construction operations in the vicinity of MP 10. 9 to MP 12.0. Suspended sediments could extend as far as 1000 meters from the centerline of the proposed pipeline trench and impact an area of as much as 1,700 Acres in the vicinity of the Thimble Islands in Long Island Sound. It is significant to note that the construction operations proposed by Islander East will involve, not just the initial construction dredging of the basin and trench, but will require the backfilling of the open trench to provide cover for the installed pipe. The impacts of the dredging will be effectively doubled. It was demonstrated that sediment deposits of up to 2.7 mm could result from the dredging operations in areas adjacent to the trench and that the backfilling operations could potentially double that accumulated mass.

The disposition of the dredged materials have not be completely described by the Islander East Pipeline Company, LLC. Alternatives include: placing of approximately 10,000 cy into the trench for protective cover of the installed pipeline; disposing of the remaining materials at the open water disposal sites in Long Island Sound; disposing of the remaining materials at yet undefined upland sites; covering the installed pipeline with engineered backfill; or a combination of each of these methods. It is anticipated that between 41,000 and 51,000 cy of the materials dredged from the HDD basin and pipeline trench could be disposed at the open water disposal facilities in Long Island Sound. It is essential that these materials be sufficiently characterized, including biological assessments, in accordance with the letter and intent of the Federal Marine Protection, Research and Sanctuaries Act.

JOHN C. ROBERGE, P.E., LLC

It is essential that the potential impacts upon pelagic, demersal and benthic fauna as well as subtidal flora imposed by the sedimentation processes be evaluated and quantified. Mitigation measures and operational constraints should be considered by regulatory authorities to minimize potential impacts. Similar dredging and construction operations have included a range of effective measures, including but not limited to:

Restricted temporal windows for operations to assure minimizing impacts upon potentially effected fauna and flora, including restriction of operations during the spawning periods of species indigenous to the project area;

Prohibition of stockpiling or sidecasting of dredged materials, requiring temporary storage of those materials on sealed floating barges;

Implementation of sealed dredge buckets to minimize re-entrainment and release of sediments into the water column during hauling operations;

Environmental sensitivity training for all dredge operators to assure knowledge of means and methods to minimize sediment release into the wqater column during dredging;

Imposing operational limits for sediment plume release size and concentration upon the dredging contractor and require termination of the dredging should those limits be exceeded;

Requiring "third-party oversight" of all operations and monitoring and assigning authorization to that entity to shut down the operations should operational limits be exceeded;

Requiring the dredging contractor to prepare and implement a *Construction Mitigation Plan*, clearly defining all of the means and methods which he proposes to employ to minimize construction impacts.

Imposing strict *Best Management Practices* upon the trench backfilling operations by requiring sediment plume size to be limited, imposing placement methodology restrictions, and related restrictions.

JOHN C. ROBERGE, P.E., LLC

1.0   Potential Turbidity Plume and Sediment Deposition From Dredging Operations

1.1   Introduction

The 24" natural gas pipeline, proposed to be placed on the bottom of Long Island Sound and extend from Branford, CT to Wading River, NY, will include a dredged basin to accommodate the transition from the HDD operation and a 1.2 mile long pipeline trench to be excavated by traditional mechanical dredging operations (Islander East Pipeline Company, LLC, Ref. 1). It was originally proposed by the project proponent that materials dredged from the transition basin and the pipeline trench would be placed on the ocean bottom in mounds adjacent to the dredged areas. Islander East Pipeline Company, LLC revised this proposed dredged material management method to that described in their "Amendment to the Structures, Dredging and Fill Permit Application - Construction Installation Modifications, (OLISP) Permit #200200761" and dated March 14, 2003 (Islander East Pipeline Company, LLC, Ref. 2). The modified method is to include placement of the dredged materials on barges. The proponent further notes that they propose to backfill the trench after placement of the pipeline to a depth such that 18" of cover are provided over the pipe. No further clarification of the methodology is provided in the permit modification document. It would appear that the ultimate fate of a significant volume of the material removed from the basin and trench, i.e. in fact approximately 78% of the material to be dredged, has not be identified. The proponent has noted that they are "consulting with federal agencies on wether to dispose of the dredged materials offsite and/or return the material to the trench". It can be assumed that Islander East Pipeline Company, LLC will seek further modification of the permit to relocate those dredged materials not used in backfilling the trench, amounting to approximately 40,000 CY, to the open water disposal sites in Long Island Sound and that all necessary, required and currently valid mechanical, chemical, and biological characteristics will be quantified prior to issuance of any dredging authorization by both Federal and State of Connecticut regulatory agencies.

It is anticipated that the HDD transition basin will be located near Mile Post 10.95. This basin is proposed to be approximately 250' in length and 130' in width with a maximum depth of 20'. The dredged pipeline trench will extend from the transition basin to Mile Post 12.0. Water depths in this area were readily available from NOAA navigation charts. The transition basin and dredged pipeline trench areas are characterized by a gently sloping bottom, with depths ranging from approximately 12' (MLW) in the area of the transition basin to about 22' (MLW) at the southern extent of the trench. Approximately 6,500 cy of sediment will be dredged from the basin and placed on the barges as currently proposed by Islander East Pipeline Company, LLC. As noted, the ultimate fate of about 78% of that volume has not been identified.

The pipeline trench will be dredged by mechanical bucket dredge. The trench will be dredged to a depth of approximately 8' below the natural bottom and anticipated side slopes of 3:1, creating a trapezoidal section. Approximately 44,680 cy of sediment will be removed from the trench and placed

onto barges as described above. After the 24" pipeline is placed into the trench, it is anticipated that a portion of the dredged materials will be used to backfill the trench and provide 18" of cover over the pipe. Islander East Pipeline Company, LLC has not identified the ultimate disposition or use of the materials remaining from the dredging operations. Neither the placement methodology nor the Best Management Practices (BMP's) to be employed by Islander East Pipeline Company, LLC during the backfilling operations have been identified. The effects of the potentially significant turbidity and material deposition within sensitive benthic communities which could result from the backfilling operations have not been quantified by Islander East.

1.2   Background

Dredging operations at the transition basin and along the pipeline trench route have the potential to affect local sediment transport systems and/or the local ecosystems. Evaluation of each of these sites included an estimate of the worst-case suspended sediment plume which could result during the dredging procedures and an estimate of potential sediment deposition depths in areas adjacent to the trench and pipeline construction. The worst-case plume condition was approximated using empirical information, available for the site or available from representative historic dredging operations and reported in available literature.

The potential spatial impacts of the transition basin construction and the trenching operations included a quantitative estimate of the mass of sediment which could impact adjacent resources. Potential suspended sediment levels were quantified utilizing the steady governing equation for a dynamically passive suspended plume (Teeter, Ref. 3). As noted, this assessment will yield worst-case centerline concentrations, demonstrating maximum potential impacts of the plume on adjacent resources. The direction of plume propagation was assumed to be coincident with the direction of the predominant tidal currents at each site, as predicted by NOAA. The tidal current vectors used in this assessment vary from those employed by the Islander East Pipeline Company, LLC. That variation is discussed in this analysis.

1.3   Historical Experience

Observations of pipeline trenching operations (Bohlen, Ref. 4) in Long Island Sound were made in 1991 to quantify potential sedimentation impacts upon adjacent oyster beds. The trenching operations included excavation of a trench, utilizing a large volume (13-22 CY) mechanical clamshell dredge, sidecasting the dredged materials along the adjacent margin of the trench, and backfilling of the trench from the margin after the pipeline was placed. The bottom materials at this site were primarily medium sands with occasional intrusions of coarse sands, gravel and mixtures of silt. The observation area was characterized by background concentrations of suspended materials which averaged between 5 and 10 mg/L. The Long Island Sound data indicated that suspended sediment concentrations within the turbidity plumes, associated with the pipeline installation procedures, decayed rapidly with distance downstream with the majority of sediment resuspended by the dredge settling within 30 -

60 m of the operation. The field observations noted further that suspended sediment concentrations within the immediate vicinity of the dredge bucket ranged from 50 to 250 mg/L. These observations appear to be consistent with other dredging operations performed in both sand and fine grained materials (Bohlen, Ref. 5). Comparable values for a range of bottom material types are shown in Table 1. The observations further noted that the near-bottom suspended material field was essentially confined to a region extending between 450 m and 920 m downstream of the operating dredge.

Table 1
Historical Suspended Sediment Plume Characteristics
For Dredging Operations

Location	Water Depth (m)	Ave. Current Speed (cm/s)	Distance From Source (m)	Ave. Sediment Concentration (mg/L)
Hori River Nagoya, Japan Watertight Bucket (Ref. 6) (Note 1)	0.5 1.5 2.5 0.5 1.5 2.5 0.5 1.5 2.5	n/a	7 7 7 13 13 13 23 23 23	105 70 20 - 25 13 - - 30
St. Johns River Jacksonville, FL (Ref. 7)	5.18	4.9	15 30 61 122 244	48 214 118 50 24
Black Rock Harbor Bridgeport, CT (Ref. 7)	6.1	6.7	30 61 122 244 488	281 179 95 58 77
Thames River New London, CT (Ref. 5)	11.0	15	33 66 100 166 233 330	86 37 22 7 5.5 3.5

Note 1:   Open bucket of similar size resulted in average sediment concentrations 1.56 times greater than closed bucket.

The dredging operations summarized on Table 1 were performed at sites with sediment characteristics comparable to the Islander East sites in the vicinity of the Thimble Islands in Branford, CT. The Hori River site included sediments which were predominantly clay and silt in water depths of approximately 3 m. The St Johns River operations were performed in silty sediments. Comparable bucket dredging operations in Black Rock Harbor and the Thames River included the dredging of primarily fine grained sands and silts. The plume generation associated with the Long Island Sound trenching work appeared to be confined to the dredge operational period with suspended sediment concentrations returning to pre-project levels almost immediately following cessation of the trenching operations. As noted (Bohlen, Ref. 4), this factor serves to reduce the time during which benthic or sessile organisms will be exposed to elevated suspended material concentrations.

It was further noted (Bohlen, Ref.4), based upon the Long Island Sound trenching observations, that the discrete nature of the pipeline construction techniques suggested that it is appropriate to treat the operation as a moving point source of suspended materials. The source of suspended sediment will move progressively along the axis of the pipeline with resulting suspended materials distributed to either side of the pipeline under the alternating influence of local tidal currents.

1.4   Assessment of Proposed Dredging Operations

To assess the potential spatial impacts of the Islander East dredging operations and to provide a quantitative estimate of the mass of sediment which could potentially impact adjacent resources, the dredging locations were evaluated utilizing the steady governing equation for a dynamically passive suspended plume (Teeter, Ref. 3). Simplifying the governing equation to a one-dimension expression, the solution for suspended sediment concentrations along the resulting plume centerline was expressed as:

$$C = [Q_s / (2HV_sX)] \; e^{-(PWX/HU)}$$

Where: C = Depth Averaged Suspended Sediment Concentration, mg/L
     Q_s = Release Rate of Suspended Material at Source, g/s
     H = Depth, m
     U = Current Speed, cm/s
     V_s = Horizontal Diffusion Velocity = 0.11(U)
     P = Depositional Probability
     W = Sediment Settling Velocity
     X = Distance From Source, m

The expression was simplified to $C = [Q_s / (2HV_sX)]$ since the maximum value of the exponential term is unity. It is anticipated that this simplification will yield conservatively high or worst-case centerline concentrations, demonstrating maximum potential impacts of the plume on adjacent

resources. The direction of plume propagation was assumed to be coincident with the direction of the predominant tidal currents at each site. Solving the one-dimensional expression for various values of X, distance from the source, correcting that distance to determine the distance normal to the trench centerline, and tabulating the results generates a series of characteristic suspended sediment concentrations, C, for each location. The distance, d, normal from the centerline of the pipeline trench, was determined by the simple computation:

$$d_{Flood} = X_{Flood} \sin(a)_{Flood} \quad \text{or} \quad d_{Ebb} = X_{Ebb} \sin(a)_{Ebb}$$

Where: d = Distance Normal From the Pipeline Axis
          X = Modeled Distance From Source
          a = Angle Between Tidal Current Direction and Pipeline Axis

The strength of the sediment source, R, is an empirical quantity. The value of the source strength, as generated by mechanical bucket dredge operations, has been observed (Collins, Ref. 7) to be dependent upon equipment geometry, operating characteristics such as speed and cycle time, depth of influence, and related characteristics.

Typical values of depth-averaged suspended sediment concentrations along the centerline of dredge buckets during water entry and withdrawal operations ranged between 50 - 500 mg/L. Typical values of initial sediment source release rates, as observed at several comparable operations, are summarized in Table 2. These values are typical of open bucket, and in several cases include closed-bucket, dredging operations and were used to quantify the range of potential impacts which could result from the Islander East dredging operations.

Table 2
Open Bucket Resuspended Sediment Source Strengths (Ref. 7)

Site	Source Strength, R (g/s)	Observed Source Concentration, (mg/L)
Black Rock Harbor	1,684	520
Calumet River	243	75
St. Johns River Jacksonville, FL	445	250 (Open Bucket) 150 (Closed Bucket)
Lake City (Note 1)	n/a	55 (Open Bucket) 150 (Closed Bucket)

Note 1: Sidecasting operations

The limit of the zone of influence was chosen to be that distance at which the ambient velocity was equivalent to the critical velocity (V_{CRIT}) required to maintain suspension of quartz sediments coarser than 200M (Vannoni, Ref. 8). V_{CRIT} for these sediments will be about 0.42 ft/s. The extent of the zone of influence, or the distance over which the initial sedimentation would take place will be approximately 55-ft or about 17-m. It was assumed that the released sediments at the dredging locations would be suspended over the entire water column due to the relatively shallow depths at these sites and that the coarse fractions would settle within 17m of either side of the trench. The characteristics of the Islander East dredging locations are summarized on Table 3. The general site characteristics include the site name, water depth, anticipated trenching technique, tidal current speeds, and average current directions referenced from the pipeline axis.

Plume generation and sedimentation potential at the dredging sites were simulated, based upon various initial sediment release rates. The sites are characterized by relatively typical sediment types. Each site includes observed fine lean clay and elastic silts, clays and traces of organics. The sediments were shown to display moderate plasticity. The average total unit weight of samples taken from the study areas, as reported by the project proponent, ranged from 89.6 to 94.9 pcf.

Table 3
Islander East Site Characteristics

Characteristic	Site		
	MP 10.90	**MP 11.5**	**MP 12.0**
Trenching Method	Mechanical Dredging	Mechanical Dredging	Mechanical Dredging
Depth, m (MLW)	4.0	5.1	6.4
Peak Flood Current, cm/s	57.0	57.0	57.0
Direction of Flood Flow	265°	265°	265°
Peak Ebb Current, cm/s	72.0	72.0	72.0
Direction of Ebb Flow	82°	82°	82°

The results of the Islander East plume simulation, detailed on the computation sheets provided in Appendix A, are summarized in Table 4. These tabulated values represent the potential increase, above ambient conditions, which could be expected for suspended sediment concentrations resulting from the basin construction and trenching operations. It must be noted that the initial rate of sediment release and thus the sediment plume characteristics will be highly dependent upon the travel speed of the dredge bucket, skill of the operator, quality of the bucket and scow equipment, and related operational issues. Variation of the travel speed with depth, sediment types, wind and wave conditions, surface support efficiency and other unforseen conditions should be anticipated.

Table 4
Islander East Pipeline Construction
Potential Suspended Sediment Concentrations At Centerline of Turbidity Plume (mg/L)

R=1,684 g/s

Station	Current Condition	Normal Distance From Trench Centerline, m (Note 1)							
		5	20	80	100	200	300	400	1000
MP 10.9	Flood	671	168	42	34	17	11	8	3
	Ebb	354	89	22	18	9	6	4	2
MP 11.5	Flood	527	132	33	26	13	9	7	3
	Ebb	299	75	19	15	7	5	4	1
MP 12.0	Flood	420	105	26	21	10	7	5	2
	Ebb	253	63	16	13	6	4	3	1

R=445 g/s

Station	Current Condition	5	20	80	100	200	300	400	1000
MP 10.9	Flood	177	44	11	9	4	3	2	1
	Ebb	94	23	6	5	3	2	1	0
MP 11.5	Flood	139	35	9	7	3	2	2	1
	Ebb	79	20	5	4	2	1	1	0
MP 12.0	Flood	111	28	7	6	3	2	1	1
	Ebb	67	17	4	3	2	1	1	0

$$R=243 \text{ g/s}$$

MP 10.9	Flood	97	24	6	5	2	2	1	0
	Ebb	51	13	3	3	1	1	1	1
MP 11.5	Flood	76	19	5	4	2	1	1	0
	Ebb	43	11	3	2	1	1	1	0
MP 12.0	Flood	61	15	4	3	2	1	1	0
	Ebb	37	9	2	2	1	1	0	0

Note 1:   Does not include dredged materials relocated to the immediate vicinity of the trench.

The results of the suspended sediment plume analyses are graphically depicted on Figures 1 - 4, as provided in Appendix A of this report. Figure 1 depicts the approximate route of the proposed pipeline and position of the HDD transition basin. The project site is located west of the Thimble Islands in relatively shallow water. Figure 2 depicts the approximate spatial limits of the potential plume which would be formed by the dredging operations and assuming a sediment release rate of 1,684 g/sec.

The sediment release rate is an empirical value, determined from literature describing comparable dredging operations. Sediment is released from the dredging site through a combination of actions, including but not necessarily limited to: the dredge bucket impacting the ocean bottom; dragging of the bucket on the bottom; the shedding of sediments from the bucket as it is hauled through the water column; and related operational parameters. While an empirical sediment release rate of 1,684 s/sec is the highest observed at other sites, it must be assumed that such rates are likely to be realized at the Islander East site based upon their lack of identified Best Management Practices and commitment to operational controls.

For comparison, the analyses included development of potential suspended sediment plumes for lower observed sediment release rates. Figures 3 and 4 provide graphic representations of the extent of the likely plumes which would result from dredging operations with sediment release rates of 445 g/sec and 243 g/sec, respectively.

The quasi-steady tidal current vectors, employed in these analyzes, were based upon the observed tidal vectors as reported by the National Oceanic and Atmospheric Administration and universally reported in commonly used tide charts and related publications. These analyzes represent the maximum conditions that can be anticipated at the project site. Site specific tidal current observations, reported by the project proponent (Bohlen et. al, Ref. 9), indicated that maximum near-bottom tidal currents were approximately 45 cm/sec, with flooding currents typically exceeding ebb. Bohlen further notes a general net transport to the northwest resulting from the asymmetry of the tidal

current intensities. He notes that the nearshore reaches of the project site will be influenced by the islands and rocky outcrops and that net transport results from a dominance of the ebb currents in a generally northeast direction. He notes further that his observations clearly reflect the importance of wind induced velocities in these shallow water areas. The Bohlen report concludes "that the plume of sediments resuspended by the dredge will for the most part spread laterally to the east and west of the trench centerline due to the dominance of the east-west tending tidal currents."

The results of the analyses provided in tabular format and graphically depicted in Appendix A, clearly demonstrate the east-west tendency for plume dispersion. Magnitudes of turbidity concentration are dependent upon the magnitude of the tidal current velocity employed in these numerical simulations. Maximum tidal current velocities, representative of near-surface NOAA observations, were employed to generate potentially "worst-case" conditions which will result from the dredging operations. The time of dredging, position of the dredge, time in the tidal cycle, and related daily operational conditions can not specifically predicted and modeling all of the permutations and combinations of these performance criteria would be an overwhelming task. Consequently, demonstrating the "worst-case" operational scenario, by assuming maximum potential near-surface tidal currents and maximum sediment release rate represents a maximum potential impact to the surrounding benthic communities. No less than the maximum impact should be used to evaluate the impacts imposed by this proposed dredging operation.

It was estimated that a conservative approximation of deposited sediment thickness, resulting from the generated turbidity plume in the areas adjacent to the trench, could be developed by assuming that all of the materials suspended into the turbidity plume would be deposited at the maximum extent of transport. The deposition of sediment suspensions is analogous to marine gravity currents (Simpson, Ref.10). The mechanics of settlement at these sites, based upon the relatively high initial concentrations, will be dominated by the mass settlement of the suspension as opposed to gravimetric settlement of individual fine particles. The relatively fine characteristics of the sediment suspensions anticipated at these sites will result in visible plumes over a fairly broad expanse adjacent to the pipeline trench and as influenced by the local tidal currents.

Table 5 summarizes these estimated layer thickness as a function of distance, normal to the pipeline axis. This anticipated deposition will generally be a relatively thin veneer of typically mobile sediments. It is anticipated that the coarser fractions of the trench excavation will be placed immediately adjacent to the trench. These materials will be used to backfill the trench after the pipeline is placed. The anticipated thickness of deposition, as simulated in these analyzes, clearly demonstrate a direct relationship to suspended concentrations of sediments within the plume and to distance from the trenching operation. The orientation of the plume drift, represented in these analyzes by the relative direction of tidal currents to the axis of the pipeline, will significantly impact the location of the plume and thus the resulting deposition pattern.

Table 5
Islander East Pipeline Construction
Potential Deposited Sedimentation Layer Resulting From Turbidity Plume, cm

Sediment Release Rate From Dredge Bucket, R = 1,684 g/s

Station	Current Condition	Normal Distance From Trench Centerline, m							
		5	20	80	100	200	300	400	1000
MP 10.95	Flood	0.27	0.04	0.01	0.01	0.01	0.0	0.0	0.0
	Ebb	0.14	0.04	0.01	0.01	0.0	0.0	0.0	0.0
MP 11.5	Flood	0.25	0.04	0.01	0.01	0.01	0.0	0.0	0.0
	Ebb	0.14	0.04	0.01	0.01	0.0	0.0	0.0	0.0
MP 12.0	Flood	0.24	0.04	0.01	0.01	0.01	0.0	0.0	0.0
	Ebb	0.14	0.04	0.01	0.01	0.0	0.0	0.0	0.0

Sediment Release Rate From Dredge Bucket, R=445 g/s

Station	Current Condition	5	20	80	100	200	300	400	1000
MP 10.95	Flood	0.07	0.01	0.0	0.0	0.0	0.0	0.0	0.0
	Ebb	0.04	0.01	0.0	0.0	0.0	0.0	0.0	0.0
MP 11.5	Flood	0.07	0.01	0.0	0.0	0.0	0.0	0.0	0.0
	Ebb	0.04	0.01	0.0	0.0	0.0	0.0	0.0	0.0
MP 12.0	Flood	0.06	0.01	0.0	0.0	0.0	0.0	0.0	0.0
	Ebb	0.04	0.01	0.0	0.0	0.0	0.0	0.0	0.0

Sediment Release Rate From Dredge Bucket, R=243 g/s

Station	Current Condition	5	20	80	100	200	300	400	1000
MP 10.95	Flood	0.04	0.01	0.0	0.0	0.0	0.0	0.0	0.0
	Ebb	0.02	0.01	0.0	0.0	0.0	0.0	0.0	0.0
MP 11.5	Flood	0.04	0.01	0.0	0.0	0.0	0.0	0.0	0.0
	Ebb	0.06	0.01	0.01	0.01	0.0	0.0	0.0	0.0
MP 12.0	Flood	0.03	0.01	0.0	0.0	0.0	0.0	0.0	0.0
	Ebb	0.02	0.01	0.0	0.0	0.0	0.0	0.0	0.0

1.5 Trench Backfilling

The pipeline trench will be dredged by mechanical bucket dredge. The trench will be dredged to a depth of approximately 8' below the natural bottom and will include side slopes of 3:1, creating a trapezoidal section as shown in Figure 5 of this report. Approximately 51,180 cy of sediment will be removed from the HDD basin and pipeline trench and placed onto barges as described above. After the 24" pipeline is placed into the trench, it is anticipated that a portion of the dredged materials will be used to backfill the trench and provide 18" of cover over the pipe.

The backfilling operation will require the placement of approximately 10,000 cy of material to be dropped or transported through the water column over the basin and trench. The proponent has noted that they are "consulting with federal agencies on wether to dispose of the dredged materials offsite and/or return the material to the trench". It can be assumed that Islander East Pipeline Company, LLC will seek further modification of the permit to relocate those dredged materials not used in backfilling the trench, amounting to approximately 41,180 cy, to the open water disposal sites in Long Island Sound and that all necessary, required and currently valid mechanical, chemical, and biological characteristics will be quantified prior to issuance of any dredging authorization by both Federal and State of Connecticut regulatory agencies.

As depicted in Figure 5, approximately 22% of the material removed from the trench will be used for backfilling and pipeline cover. More than 41,000 cy of dredged materials will have to be disposed as a result of this proposed operation. Islander East Pipeline Company, LLC has not identified the ultimate disposition or use of the materials remaining from the dredging operations. The methodology or Best Management Practices (BMP's) to be employed by Islander East Pipeline Company, LLC during the backfilling operations have not been identified. The effects of the potentially significant turbidity and material deposition within sensitive benthic communities which could result from the backfilling operations have not been identified by Islander East.

It is reasonable to conclude that the basin and trench backfilling operations could result in elevated suspended sediment levels at least equivalent to those which have been demonstrated to characterize the dredging operations. The potential impacts of the dredging, as summarized in Tables 4 and 5 of this report, could be effectively doubled by the backfilling.

2.0 Dredged Material Management

The original pipeline construction operations included the proposed sidecasting of the dredged sediments into mounds, placed along the perimeter of the transition basin and pipeline trench. These mounds were expected to extend between 10' and 11' above the natural bottom. The crests of these mounds would be positioned between 2' and 10' below the water surface during periods of low tide. It was evident that these mounds, in addition to presenting severe restrictions and significant hazards to local navigation, would be exposed to erosion processes imposed by wind generated waves which

characterize this site. Sediments placed into these mounds and suspended by waves, would enter the water column and be transported from the site by tidal currents and related mechanisms.

As a result of the obvious potential environmental impacts imposed upon the surrounding benthic resources, Islander East Pipeline Company, LLC revised this proposed dredged material management method to that described in their "Amendment to the Structures, Dredging and Fill Permit Application - Construction Installation Modifications, (OLISP) Permit #200200761" and dated March 14, 2003 (Islander East Pipeline Company, LLC, Ref. 2). The modified method is to include placement of the dredged materials on barges. The modified methodology notes that they propose to backfill the trench after placement of the pipeline to a depth 18" over the placed pipe. Figure 5 provides a graphic representation of the typical trench section. No further clarification of the methodology is provided in the permit modification document. The ultimate fate of a significant volume of the material removed from the basin and trench, i.e. in fact approximately 78% of the material to be dredged, has not be identified. The proponent has noted that they are "consulting with federal agencies on wether to dispose of the dredged materials offsite and/or return the material to the trench". It can be estimated that approximately 10,000 cy of the dredged materials will be used for backfilling of the trench. That material will have to be placed by mechanical dredge or dumped from the barges on which the material is proposed to be stored.

It can be assumed that Islander East Pipeline Company, LLC will seek further modification of the permit to relocate those dredged materials not used in backfilling the trench, amounting to more than 41,000 cy, to the open water disposal sites in Long Island Sound and that all necessary, required and currently valid mechanical, chemical, and biological characteristics will be quantified prior to issuance of any dredging authorization by both Federal and State of Connecticut regulatory agencies.

2.1   Background

The processes involved in the resuspension and transport of bottom sediments in shallow marine environments are highly complex and difficult to describe because each of the key mechanisms involving water movement and water-sediment interaction are, in themselves, complex. Weggel (Ref. 11) notes that suspended sediments are generally smaller than materials transported near the bottom. Weggel concludes that, regardless of the mode of transport, several prerequisites for net sediment movement can be identified. These include: (1) a source of movable sediment must be available; (2) a mechanism for initiating sediment movement is required; and (3) an asymmetry in the sediment motion must be present. Each of these prerequisites is present at the Islander east site.

The dredged material mounds would have provided a ready source of movable sediment. While the bottom materials appear to show plastic characteristics associated with cohesive sediments, the materials would be significantly disturbed during dredging resulting in higher water content than found in the in-situ state, thus more readily movable. The shallow bathymetry along the entire dredging route can be significantly influenced by wind generated shallow water waves. These waves,

particularly those associated with storm events, would provide more than adequate energy to re-suspend and lift the dredged sediments off the mounds. Once suspended by the generally symmetrical flow regime associated with passing waves, net transport of these sediments suspended from the mounds would be a function of the tidal currents which characterize the area.

The U.S. Army Corps of Engineers (Douglass, et al., Ref. 12) acknowledges the ability of currents and waves to resuspend and transport sediments which have been placed on the ocean bottom during underwater placement operations associated with dredging projects. The U.S. Army Corps of Engineers' studies involved the monitoring of several submerged mounds or berms of generally non-cohesive dredged materials placed on the bottom of Mobile Bay. It was noted that faster peak speed of water particles under wave crests appears to be the dominant mechanism which moved these submerged berms.

2.2 Assessment of Potential Sediment Mound Erosion

It is clear that dredged material mounds, originally proposed to be placed adjacent to the transition basin and trench as a part of the Islander East pipeline construction work, could be subject to resuspension and transport via mechanisms which are typical of the site. The site is subject to storm events, most typically associated with hurricanes and nor'easter's which impact the region. These meteorological conditions typically generate wind waves originating over the open water fetches to the south and southwest of the Thimble Islands. Storm wave conditions, which can be expected at this site are summarized in Table 6. These wave characteristics were computed using the Sverdrup-Munk-Bretschneider (SMB) empirical approximation for shallow water waves as detailed on the computation sheets provided in Appendix B. The potential wave conditions were developed for a range of wind conditions which can be experienced over Long Island Sound. These conditions represent the 100-Year recurrence interval (1% chance of annual exceedence), the 50-Year recurrence interval (2% chance of annual exceedence), and the 2-Year recurrence interval (50% chance of annual exceedence).

Table 6
Characteristic Storm Wave Conditions Effecting the Project Site

Recurrence Interval	Wind Speed (mph)	South Fetch			Southwest Fetch		
		Fetch Length (mi)	Wave Characteristics		Fetch Length (mi)	Wave Characteristics	
			H_S (ft)	T (sec)		H_S (ft)	T (sec)
100-Yr	100	20.4	20.0	8.0	54.0	24.5	10.0
50-Yr	90		17.8	7.6		22.0	9.6
2-Yr	50		9.4	6.0		12.9	7.5

These wave characteristics represent the deepwater conditions of the significant wave, i.e the average of the highest 1/3 of the waves that would be generated by the representative wind blowing over the indicated fetch distance for a duration sufficient to fully develop the wave set. The required duration for the tabulated waves ranged between 2.4 hours and 6 hours. The water depths at the project site range between approximately 10' and 20', referenced to local mean low water. Water surface elevations can vary with tidal stage and coastal flooding conditions throughout Long Island Sound, but the relatively shallow conditions along the entire trench route will likely lead to breaking wave conditions, thus introducing sediment transport mechanisms similar to those on a beach face.

Table 7
Wave Induced Near-Bottom Horizontal Velocities at Dredge Mound Locations, ft/s

Recurrence Interval	Maximum Anticipated Bottom Velocities, ft/s		
	MP 10.9	MP 11.5	MP 12.0
100-Yr	12.3	13.8	13.9
50-Yr	12.3	13.7	12.3
2-Yr	9.2	7.9	6.8

Note 1:   To convert ft/s to cm/s multiply ft/s by 30.48.   Example - 6.8 ft/s x 30.48 = 207.3 cm/s or 2.07 m/s.

As noted from the literature citations, the primary mechanism for resuspending sediments from the proposed sediment mounds would be the movement of water induced by the passage of waves over the site. As waves translate past a position on the shallow ocean bottom, the water particles within the water column beneath the wave, will move in an orbital motion. Each water particle will assume a vertical and horizontal displacement. The size of the orbital motion and velocity of the vertical and horizontal water movement is dependent upon the wave height and period and upon the depth of water. Table 7 provides a summary of potential near-bottom wave orbital velocities which would be associated with the possible storm wave conditions at the project site.

Figure 6, provided in Appendix A, is a summary of empirical observations of sediment movement under wave action. This data clearly demonstrates that fine sediments, similar to those originally proposed to be placed in the mounds would likely be moved by water velocities exceeding 10 cm/sec. The potential near-bottom wave orbital velocities which can be realized at these sites during storms can be an order-of-magnitude greater than the threshold velocities for sediment motion. Disregarding the effects of waves breaking on the mounds, an evaluation of these near-bottom velocities revealed that the magnitude of these velocities would be sufficient to mobilize all of the materials that would have been placed in the sidecast mounds. The total volume of sediments which could be resuspended from the mounds would be dependent upon the duration of the wave impacts upon the site and upon the depth of the boundary motion at the water-sediment interface. However, the relatively significant

turbulence which will be associated with storm wave passage in combination with the high orbital velocities would dislodge and transport sediments from these sites.

Sediment particles would be resuspended and transported from the mound position with the passing of each wave. The maximum anticipated period of a storm generated surface wave at the construction sites was demonstrated to be 10 seconds. It can be estimated that horizontal velocities of sufficient magnitude to mobilize the sediments will occur over approximately one-half of the wave period. It is therefore reasonable to argue that conditions favorable for erosion of the sediment mounds could persist for at least one-half of the time that the storm waves influence the site. A storm of 6-hour duration could potentially erode the entire mound system and place those materials into suspension. The mobilized sediments would be transported into adjacent waters and sensitive benthic habitat.

2.3 Dredged Material Management Alternatives

The modified construction methods, proposed by Islander East Pipeline Company, LLC, will require the disposition of more than 51,000 cy of materials removed from the HDD basin and pipeline trench. The five (5) general alternatives include:

Placement of the excavated sediments into the basin and trench to provide cover for the pipe and to restore the bottom to near pre-construction grade;

Placement of approximately 10,000 cy of the dredged sediments into the trench as cover for the pipeline and disposal of the remaining 41,000 cy of dredged materials at an upland disposal facility;

Placement of approximately 10,000 cy of the dredged sediments into the trench as cover for the pipeline and disposal of the remaining 41,000 cy of dredged materials at the Open Water Dredged Material Disposal sites in Long Island Sound;

Placement of approximately 10,000 cy of engineered backfill into the trench as cover for the pipeline and disposal of the 51,000 cy of dredged materials at an upland disposal facility; or

Placement of approximately 10,000 cy of engineered backfill into the trench as cover for the pipeline and disposal of the 51,000 cy of dredged materials at the Open Water Dredged Material Disposal sites in Long Island Sound.

As noted in previous sections of this report, placement of the dredged materials back into the basin and trench will expose the Thimble Island region to elevated turbidity levels and potential deposition of mobilized sediments onto sensitive benthic habitat areas. The magnitude of the impacts can be based upon the general results of the dredging impact assessment.

Open water disposal of dredged materials is regulated by both the U.S. Army Corps of Engineers and the State of Connecticut, Department of Environmental Protection, Office of Long Island Sound Programs (OLISP). Open water disposal of more than 25,000 cy of dredged materials requires compliance with the Federal Marine Protection, Research and Sanctuaries Act (Ambro amendment). It is essential that all reviewing agencies, including but not limited to the U.S. Environmental Protection Agency, U.S. Fish & Wildlife, and others, review the specific dredging and dredged material disposal plan proposed by Islander East Pipeline Company, LLC. It is essential that all required and currently valid mechanical, chemical, and biological characteristics of the dredged materials be quantified prior to issuance of any dredging authorization by the Federal and State of Connecticut regulatory agencies.

3.0   Summary and Conclusions

It was demonstrated that turbidity levels and sediment deposition, resulting from the proposed construction of the Islander East Pipeline Company, LLC natural gas pipeline, will potentially and significantly impact the adjacent waters of Long Island Sound. The anticipated turbidity levels and deposition will be highly dependent upon the rate of initial sediment release at the dredging position. Empirical values of sediment release rates for comparable observed dredging operations were employed to develop limits of potential suspended sediment plumes which could result from the pipeline construction operations in the vicinity of MP 10. 9 to MP 12.0. Suspended sediments could extend as far as 1000 meters from the centerline of the proposed pipeline trench and impact an area of as much as 1,700 Acres in the vicinity of the Thimble Islands in Long Island Sound. It is significant to note that the construction operations proposed by Islander East will involve, not just the initial construction dredging of the basin and trench, but will require the backfilling of the open trench to provide cover for the installed pipe. The impacts of the dredging quantified in the text will be effectively doubled. Sediments transported by local tidal flows away from the construction site will be deposited on the bottom areas adjacent to the trench.

The original proposed construction work included placing the materials dredged from the HDD transition basin and the pipeline trench into mounds adjacent to the areas of excavation. This construction methodology has been modified. Islander East Pipeline Company, LLC currently proposes to store those dredged materials on barges and either use them as cover over the installed pipeline or dispose of them in the open water disposal sites in Long Island Sound or at upland offsite facilities.

The disposition of the dredged materials have not be completely described by the Islander East Pipeline Company, LLC. It is anticipated that between 41,000 and 51,000 cy of the materials dredged from the HDD basin and pipeline trench could be disposed at the open water disposal facilities in Long Island Sound. It is essential that these materials be sufficiently characterized, including biological assessments, in accordance with the letter and intent of the Federal Marine Protection, Research and Sanctuaries Act.

It is essential that the potential impacts upon pelagic, demersal and benthic fauna as well as subtidal flora imposed by the sedimentation processes be evaluated and quantified. Mitigation measures and operational constraints should be considered by regulatory authorities to minimize potential impacts. Similar dredging and construction operations have included a range of effective measures, including but not limited to:

> Restricted temporal windows for operations to assure minimizing impacts upon potentially effected fauna and flora, including restriction of operations during the spawning periods of species indigenous to the project area;

> Prohibition of stockpiling or sidecasting of dredged materials, requiring temporary storage of those materials on sealed floating barges;

> Implementation of sealed dredge buckets to minimize re-entrainment and release of sediments into the water column during hauling operations;

> Environmental sensitivity training for all dredge operators to assure knowledge of means and methods to minimize sediment release into the wqater column during dredging;

> Imposing operational limits for sediment plume release size and concentration upon the dredging contractor and require termination of the dredging should those limits be exceeded;

> Requiring "third-party oversight" of all operations and monitoring and assigning authorization to that entity to shut down the operations should operational limits be exceeded;

> Requiring the dredging contractor to prepare and implement a *Construction Mitigation Plan*, clearly defining all of the means and methods which he proposes to employ to minimize construction impacts.

> Imposing strict *Best Management Practices* upon the trench backfilling operations by requiring sediment plume size to be limited, imposing placement methodology restrictions, and related restrictions.

4.0   References

(1)   Islander East Pipeline Company, LLC, et. al, "Islander east Pipeline Project, *Draft Environmental Impact Statement*," Federal Energy Regulatory Commission (FERC), FERC/EIS-01430, March 2002.

(2)   Islander east Pipeline Company, LLC, et. al, "Islander east Pipeline Project, Amendment to the Structures, Dredging and Fill Permit Application - Construction Installation Modifications," Permit #200200761, March 14, 2003.

(3)   Teeter, A. M., "New Bedford Harbor Superfund Project, Acushnet River Estuary, Engineering Feasibility Study of Dredging and Dredged Material Disposal Alternatives, Report 2, Sediment and Containment Hydraulic Transport Investigations", Technical Report EL-88-15, US Army Engineer Waterways Experiment Station, Vicksburg, MS, 1988.

(4)   Bohlen, W. F., "An Investigation of Sedimentation Induced By Gas Pipeline Laying Operations In the Vicinity of the Oyster Bed Lease Areas, Milford, CT", Report Prepared for Iroquois Gas Transmission System by University of Connecticut, Department of Marine Sciences, Avery Point, Groton, CT, March 1992.

(5)   Bohlen, W. F., "Factors Governing the Distribution of Dredge-Resuspended Sediments", Proceedings of the 16th Coastal Engineering Conference, American Society of Civil Engineers, Hamburg, Germany, p. 20001-2018, August 1978.

(6)   Zappi, P. A. and D. F. Hayes, "Innovative Technologies for Dredging Contaminated Sediments", Misc. Paper EL-91-20, IOMT Research Program, Department of the Army, Waterways Experiment Station, Vicksburg, MS, September 1991.

(7)   Collins, M. A., "Dredging Induced Near-Field Resuspended Sediment Concentrations and Source Strengths", Misc. Paper D-95-2, DOTS Program, US Army Engineer Waterways Experiment Station, Vicksburg, MS, August 1995.

(8)   Vanoni, V. A. (ed), Sedimentation Engineering, American Society of Civil Engineers, New York, NY, p. 101-103, 1975.

(9)   Bohlen, W.F., M.M. Howard-Strobel and M.L. Thatcher, "An Initial Evaluation of Marine Sediment Dispersion Associated with the Installation of the Islander East Natural Gas Pipeline",Prepared for Natural Resources Group, Inc., Mystic, CT, April 8, 2002.

Simpson, J. E., Gravity Currents in the Environment and the Laboratory, 2nd ed., Cambridge University Press, Cambridge, U.K., p. 140-221, 1997.

Weggel, J. Richard, " An Introduction to Oceanic Water Motions and Their Relation to Sediment Transport", Chap. 1: Water Motion and Process of Sediment Transport from *Shelf Sediment Transport*, ed. by Swift, Duane and Pilkey, Dowden, Hutchinson & Ross, Inc., Stroudsburg, PA, 1972.

Appendix A Figures 1 – 5

This document involves pipeline location information and is not available at this Internet site due to homeland security-related considerations. This portion of the Millennium Pipeline consistency appeal administrative record may be reviewed at NOAA's Office of General Counsel for Ocean Services, 1305 East-West Highway, Silver Spring, Maryland.
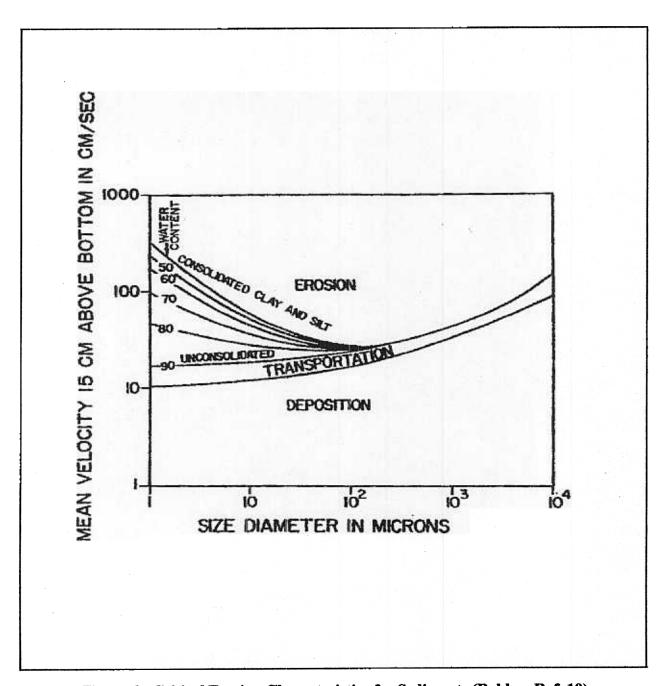
Figure 6 - Critical Erosion Characteristics for Sediments (Bohlen, Ref. 10)

Original Publication:

Basco, D.R., Bouma, A.H., and Dunlap, W.H.., "Assessment of the Factors Controling the Long-Term Fate of Dredged Material Deposited in Unconfined Subaqueous Disposal Areas, Dredged Material Research Program," Report D-074-8, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 1974.

JOHN C. ROBERGE, P.E., LLC

APPENDIX B

COMPUTATIONAL MODEL DATA

JOHN C. ROBERGE, P.E., LLC

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Project:	**ISLANDER EAST PIPELINE**	**Sheet No.**	1 of
		Job No.	Branford 200242
Subject:	**Construction Methods Assessment**	**Made By:**	Roberge Date
	Sediment Dispersion Simulation	**Chkd. By:**	Date

PIPELINE STATION:		MP 10.9	Ebb Flow Condition		R = 1,684 g/s			Case 1

TURBIDITY PLUME CENTERLINE CONCENTRATION, mg/liter

Depth, m	Current m/s	Distance From Trenching Operation, m							
		5	20	80	100	200	300	400	1000
Flood 4.00	0.57	671	168	42	34	17	11	8	3
Ebb 6.00	0.72	354	89	22	18	9	6	4	2
Average 5.00	0.66	464	116	29	23	12	8	6	2

Trenching Sediment Release Rate, R:	1684 g/s	Current Angle:	82

Basin Construction and trenching MP 10.9 to MP 12.0 – Islander East Pipeline – Thimble Islands, CT

Trench excavated by Bucket Dredge, per Islander East documents. Excavation of 272 CF / LF of trench (or about 10CY/LF). Anticipate a bucket of about 10 CY capacity. Estimate cycle speed for bucket will be about 60 sec at this shallow site. The trench advance rate will be approximately 1.0 ft/min. Considering that anchors / spud repositioning every 120 LF of trench (est. length of work barge) and that repositioning will require approx. 45 minutes - Production will be approximately 44 LF/hr. Possible that the trench will advance 270 LF during each Flood and Ebb tidal cycle.

Deposition potential was represented by the extent of the lines of constant C assuming that all of the suspended material could settle at that position. Thickness of the settled material is directly related to plume concentration.

$$\text{Thickness (cm)} = \frac{C \text{ (mg/L)} \times \text{Depth (m)}}{\text{Bulk Density (10000)}}$$

Bulk Density (g/cc) : 1.5

Deposited Sediment Layer Thickness, cm

Plume	Distance From Trenching Operation, m							
	5	20	80	100	200	300	400	1000
Flood	0.27	0.04	0.01	0.01	0.01	0.00	0.00	0.00
Ebb	0.14	0.04	0.01	0.01	0.00	0.00	0.00	0.00

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Project:	ISLANDER EAST PIPELINE	Sheet No.	1 of
		Job No.	Branford 200242
Subject:	Construction Methods Assessment	Made By:	Roberge Date
	Sediment Dispersion Simulation	Chkd. By:	Date

PIPELINE STATION: MP 11.5 Flood Flow Condition R = 243 g/s Case 12

TURBIDITY PLUME CENTERLINE CONCENTRATION, mg/liter

Depth, m	Current m/s	5	20	80	100	200	300	400	1000
				Distance From Trenching Operation, m					
Flood 5.10	0.57	76	19	5	4	2	1	1	0
Ebb 7.10	0.72	43	11	3	2	1	1	1	0
Average 6.10	0.66	55	14	3	3	1	1	1	0

Trenching Sediment Release Rate, R: 243 g/s   Current Angle: 265

Basin Construction and trenching MP 10.9 to MP 12.0 – Islander East Pipeline – Thimble Islands, CT

Trench excavated by Bucket Dredge, per Islander East documents. Excavation of 272 CF / LF of trench (or about 10CY/LF). Anticipate a bucket of about 10 CY capacity. Estimate cycle speed for bucket will be about 60 sec at this shallow site. The trench advance rate will be approximately 1.0 ft/min. Considering that anchors / spud repositioning every 120 LF of trench (est. length of work barge) and that repositiioning will require approx. 45 minutes - Production will be approximately 44 LF/hr. Possible that thetrench will advance 270 LF during each Flood and Ebb tidal cycle.

Deposition potential was represented by the extent of the lines of constant C assuming that all of the suspended material could settle at that position. Thickness of the settled material is directly related to plume concentration.

$$\text{Thickness (cm)} = \frac{C\,(\text{mg/L}) \times \text{Depth (m)}}{\text{Bulk Density (10000)}}$$

Bulk Density (g/cc) : 1.5

Deposited Sediment Layer Thickness, cm

Plume	5	20	80	100	200	300	400	1000
			Distance From Trenching Operation, m					
Flood	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Ebb	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00

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		Job No.	Branford 200242	
Subject:	**Construction Methods Assessment**	**Made By:**	Roberge	Date
	Sediment Dispersion Simulation	**Chkd. By:**		Date

PIPELINE STATION:		MP 12.0	Ebb Flow Condition	R = 1,684 g/s		Case 13

TURBIDITY PLUME CENTERLINE CONCENTRATION, mg/liter

Depth, m	Current m/s	Distance From Trenching Operation, m							
		5	20	80	100	200	300	400	1000
Flood									
6.40	0.57	420	105	26	21	10	7	5	2
Ebb									
8.40	0.72	253	63	16	13	6	4	3	1
Average									
7.40	0.66	313	78	20	16	8	5	4	2

Trenching Sediment Release Rate, R:	1684 g/s	Current Angle:	82

Basin Construction and trenching MP 10.9 to MP 12.0 - Islander East Pipeline - Thimble Islands, CT

Trench excavated by Bucket Dredge, per Islander East documents. Excavation of 272 CF / LF of trench (or about 10 CY/LF). Anticipate a bucket of about 10 CY capacity. Estimate cycle speed for bucket will be about 60 sec at this shallow site. The trench advance rate will be approximately 1.0 ft/min. Considering that anchors / spud repositioning every 120 LF of trench (est. length of work barge) and that repositioning will require approx. 45 minutes - Production will be approximately 44 LF/hr. Possible that the trench will advance 270 LF during each Flood and Ebb tidal cycle.

Deposition potential was represented by the extent of the lines of constant C assuming that all of the suspended material could settle at that position. Thickness of the settled material is directly related to plume concentration.

$$\text{Thickness (cm)} = \frac{C\,(\text{mg/L}) \times \text{Depth (m)}}{\text{Bulk Density (10000)}}$$

Bulk Density (g/cc) :	1.5

Deposited Sediment Layer Thickness, cm

Plume	Distance From Trenching Operation, m							
	5	20	80	100	200	300	400	1000
Flood	0.24	0.04	0.01	0.01	0.01	0.00	0.00	0.00
Ebb	0.14	0.04	0.01	0.01	0.00	0.00	0.00	0.00

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Project:	**ISLANDER EAST PIPELINE**	**Sheet No.**	1 of
		Job No.	Branford 200242
Subject:	**Construction Methods Assessment**	**Made By:**	Roberge **Date**
	Sediment Dispersion Simulation	**Chkd. By:**	**Date**

| **PIPELINE STATION:** | | **MP 12.0** | **Ebb Flow Condition** | | **R = 445 g/s** | | | **Case 14** |

TURBIDITY PLUME CENTERLINE CONCENTRATION, mg/liter

Depth, m	Current m/s	Distance From Trenching Operation, m

Depth, m	Current m/s	5	20	80	100	200	300	400	1000
Flood									
6.40	0.57	111	28	7	6	3	2	1	1
Ebb									
8.40	0.72	67	17	4	3	2	1	1	0
Average									
7.40	0.66	83	21	5	4	2	1	1	0

Trenching Sediment Release Rate, R:	445	g/s	Current Angle:	82

Basin Construction and trenching MP 10.9 to MP 12.0 – Islander East Pipeline – Thimble Islands, CT

Trench excavated by Bucket Dredge, per Islander East documents. Excavation of 272 CF / LF of trench (or about 10CY/LF). Anticipate a bucket of about 10 CY capacity. Estimate cycle speed for bucket will be about 60 sec at this shallow site. The trench advance rate will be approximately 1.0 ft/min. Considering that anchors / spud repositioning every 120 LF of trench (est. length of work barge) and that repositiioning will require approx. 45 minutes - Production will be approximately 44 LF/hr. Possible that the trench will advance 270 LF during each Flood and Ebb tidal cycle.

Deposition potential was represented by the extent of the lines of constant C assuming that all of the suspended material could settle at that position. Thickness of the settled material is directly related to plume concentration.

$$\text{Thickness (cm)} = \frac{C\,(\text{mg/L}) \times \text{Depth (m)}}{\text{Bulk Density} (10000)}$$

Bulk Density (g/cc) : 1.5

Deposited Sediment Layer Thickness, cm

Plume	Distance From Trenching Operation, m

Plume	5	20	80	100	200	300	400	1000
Flood	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Ebb	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00

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Project:	**ISLANDER EAST PIPELINE**	**Sheet No.**	1 of
		Job No.	Branford 200242
Subject:	**Construction Methods Assessment**	**Made By:**	Roberge Date
	Sediment Dispersion Simulation	**Chkd. By:**	Date

PIPELINE STATION:	MP 12.0	Ebb Flow Condition	R = 243 g/s	Case 15

TURBIDITY PLUME CENTERLINE CONCENTRATION, mg/liter

Depth, m	Current m/s	Distance From Trenching Operation, m							
		5	20	80	100	200	300	400	1000
Flood 6.40	0.57	61	15	4	3	2	1	1	0
Ebb 8.40	0.72	37	9	2	2	1	1	0	0
Average 7.40	0.66	45	11	3	2	1	1	1	0

Trenching Sediment Release Rate, R:	243	g/s	Current Angle:	82

Basin Construction and trenching MP 10.9 to MP 12.0 - Islander East Pipeline - Thimble Islands, CT

Trench excavated by Bucket Dredge, per Islander East documents. Excavation of 272 CF / LF of trench (or about 10CY/LF). Anticipate a bucket of about 10 CY capacity. Estimate cycle speed for bucket will be about 60 sec at this shallow site. The trench advance rate will be approximately 1.0 ft/min. Considering that anchors / spud repositioning every 120 LF of trench (est. length of work barge) and that repositiioning will require approx. 45 minutes - Production will be approximately 44 LF/hr. Possible that the trench will advance 270 LF during each Flood and Ebb tidal cycle.

Deposition potential was represented by the extent of the lines of constant C assuming that all of the suspended material could settle at that position. Thickness of the settled material is directly related to plume concentration.

$$\text{Thickness (cm)} = \frac{C\,(mg/L) \times Depth\,(m)}{Bulk\ Density\,(10000)}$$

Bulk Density (g/cc) :	1.5

Deposited Sediment Layer Thickness, cm

Plume	Distance From Trenching Operation, m							
	5	20	80	100	200	300	400	1000
Flood	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Ebb	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00

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Project:	**ISLANDER EAST PIPELINE**	Sheet No.	1 of
		Job No.	Branford 200242
Subject:	**Construction Methods Assessment**	Made By:	Roberge Date
	Sediment Dispersion Simulation	Chkd. By:	Date

PIPELINE STATION:		MP 12.0	Flood Flow Condition		R = 1,684 g/s			Case 16

TURBIDITY PLUME CENTERLINE CONCENTRATION, mg/liter

Depth, m	Current m/s	Distance From Trenching Operation, m
		5	20	80	100	200	300	400	1000
Flood 6.40	0.57	420	105	26	21	10	7	5	2
Ebb 8.40	0.72	253	63	16	13	6	4	3	1
Average 7.40	0.66	313	78	20	16	8	5	4	2

Trenching Sediment Release Rate, R:	1684 g/s	Current Angle:	265

Basin Construction and trenching MP 10.9 to MP 12.0 - Islander East Pipeline - Thimble Islands, CT

Trench excavated by Bucket Dredge, per Islander East documents. Excavation of 272 CF / LF of trench (or about 10CY/LF). Anticipate a bucket of about 10 CY capacity. Estimate cycle speed for bucket will be about 60 sec at this shallow site. The trench advance rate will be approximately 1.0 ft/min. Considering that anchors / spud repositioning every 120 LF of trench (est. length of work barge) and that repositioning will require approx. 45 minutes - Production will be approximately 44 LF/hr. Possible that the trench will advance 270 LF during each Flood and Ebb tidal cycle.

Deposition potential was represented by the extent of the lines of constant C assuming that all of the suspended material could settle at that position. Thickness of the settled material is directly related to plume concentration.

$$\text{Thickness (cm)} = \frac{C (mg/L) \times Depth (m)}{Bulk\ Density\ (10000)}$$

Bulk Density (g/cc) : 1.5

Deposited Sediment Layer Thickness, cm

Plume	Distance From Trenching Operation, m
	5	20	80	100	200	300	400	1000
Flood	0.24	0.04	0.01	0.01	0.01	0.00	0.00	0.00
Ebb	0.14	0.04	0.01	0.01	0.00	0.00	0.00	0.00

Rev. No.
Made By   Date

JOHN C. ROBERGE, P.E., LLC

File Ref. : compsht

Project:	**ISLANDER EAST PIPELINE**	Sheet No.	1 of
		Job No.	Branford 200242
Subject:	**Construction Methods Assessment**	Made By:	Roberge Date
	Sediment Dispersion Simulation	Chkd. By:	Date

| PIPELINE STATION: | | MP 12.0 | Flood Flow Condition | | R = 445 g/s | | | Case 17 |

TURBIDITY PLUME CENTERLINE CONCENTRATION, mg/liter

Depth, m	Current m/s	Distance From Trenching Operation, m
		5	20	80	100	200	300	400	1000
Flood 6.40	0.57	111	28	7	6	3	2	1	1
Ebb 8.40	0.72	67	17	4	3	2	1	1	0
Average 7.40	0.66	83	21	5	4	2	1	1	0

Trenching Sediment Release Rate, R:		445 g/s	Current Angle:	265

Basin Construction and trenching MP 10.9 to MP 12.0 - Islander East Pipeline - Thimble Islands, CT

Trench excavated by Bucket Dredge, per Islander East documents. Excavation of 272 CF / LF of trench (or about 10CY/LF). Anticipate a bucket of about 10 CY capacity. Estimate cycle speed for bucket will be about 60 sec at this shallow site. The trench advance rate will be approximately 1.0 ft/min. Considering that anchors / spud repositioning every 120 LF of trench (est. length of work barge) and that repositioning will require approx. 45 minutes - Production will be approximately 44 LF/hr. Possible that the trench will advance 270 LF during each Flood and Ebb tidal cycle.

Deposition potential was represented by the extent of the lines of constant C assuming that all of the suspended material could settle at that position. Thickness of the settled material is directly related to plume concentration.

$$\text{Thickness (cm)} = \frac{C\,(mg/L) \times \text{Depth (m)}}{\text{Bulk Density (10000)}}$$

Bulk Density (g/cc) :   1.5

Deposited Sediment Layer Thickness, cm

Plume	Distance From Trenching Operation, m
	5	20	80	100	200	300	400	1000
Flood	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Ebb	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00

Rev. No.
Made By   Date

Project:	**ISLANDER EAST PIPELINE**	Sheet No.	1 of
		Job No.	Branford 200242
Subject:	**Construction Methods Assessment**	Made By:	Roberge	Date
	Sediment Dispersion Simulation	Chkd. By:		Date

PIPELINE STATION: **MP 12.0**   **Flood Flow Condition**   **R = 243 g/s**   **Case 18**

TURBIDITY PLUME CENTERLINE CONCENTRATION, mg/liter

Depth, m	Current m/s	Distance From Trenching Operation, m							
		5	20	80	100	200	300	400	1000
Flood 6.40	0.57	61	15	4	3	2	1	1	0
Ebb 8.40	0.72	37	9	2	2	1	1	0	0
Average 7.40	0.66	45	11	3	2	1	1	1	0

Trenching Sediment Release Rate, R:	243	g/s	Current Angle:	265

Basin Construction and trenching MP 10.9 to MP 12.0 – Islander East Pipeline – Thimble Islands, CT

Trench excavated by Bucket Dredge, per Islander East documents. Excavation of 272 CF / LF of trench (or about 10 CY/LF). Anticipate a bucket of about 10 CY capacity. Estimate cycle speed for bucket will be about 60 sec at this shallow site. The trench advance rate will be approximately 1.0 ft/min. Considering that anchors / spud repositioning every 120 LF of trench (est. length of work barge) and that repositiioning will require approx. 45 minutes – Production will be approximately 44 LF/hr. Possible that the trench will advance 270 LF during each Flood and Ebb tidal cycle.

Deposition potential was represented by the extent of the lines of constant C assuming that all of the suspended material could settle at that position. Thickness of the settled material is directly related to plume concentration.

$$\text{Thickness (cm)} = \frac{C\ (mg/L) \times Depth\ (m)}{Bulk\ Density\ (10000)}$$

Bulk Density (g/cc) :   1.5

Deposited Sediment Layer Thickness, cm

Plume	Distance From Trenching Operation, m							
	5	20	80	100	200	300	400	1000
Flood	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Ebb	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00

Rev. No.
Made By   Date

JOHN C. ROBERGE, P.E., LLC

Project: Islander East Pipeline Construction			**Sheet No.** 1	**of**	
Location: Branford, CT – Long Island Sound			**Job No.** 200242		
Subject: SMB Hindcast Model with Shallow Water Correction – 100 Yr Wind / 100 Yr Depth			**Made By** Roberge **Chkd. By**	**Date** **Date**	11/26/2002

Constants

		Units	
Gravity, g	9.81	m/s^2	
Surface Wind, Us	100.0	mi/hr	Ref: Handbook of Ocean and Underwater Engineering
	44.7	m/s	Myers, Holm, McAllister, ed, McGraw-Hill, 1969, p.8-5
Wind Stress Factor, U$_A$	76.1	m/s	$U_A = 0.71 U_S^{1.23}$

Variables

	Units	Reach #1	Reach #2
Wind Direction		South	SW
Fetch Distance, F	n.mi	20.4	54.0
	m	37780.8	100008.0
Average Water Depth,	ft	88.0	82.0
	m	26.8	25.0

Calculations

	Units	Reach #1	Reach #2
Wave Height, H	m	6.1	7.5
	ft	20.0	24.5

$$H = \frac{.283 U_A^2}{g} \tanh\left[.530\left(\frac{gd}{U_A^2}\right)^{3/4}\right] \tanh\left[\frac{.00565\left(\frac{gF}{U_A^2}\right)^{1/2}}{\tanh\left[.530\left(\frac{gd}{U_A^2}\right)^{3/4}\right]}\right]$$

Wave Period, T	Units	Reach #1	Reach #2
	sec	8.0	10.0

$$T = \frac{7.54 U_A}{g} \tanh\left[.833\left(\frac{gd}{U_A^2}\right)^{3/8}\right] \tanh\left[\frac{.0379\left(\frac{gF}{U_A^2}\right)^{1/3}}{\tanh\left[.833\left(\frac{gd}{U_A^2}\right)^{3/8}\right]}\right]$$

Duration, t	Units	Reach #1	Reach #2
	hrs	2.4	4.5

$$t = 8.93 \times 10^{-1}\left(\frac{F^2}{U_A}\right)^{1/3}$$

Rev. No.		
Made By	**Date**	

JOHN C. ROBERGE, P.E., LLC

Project:	Islander East Pipeline Construction	**Sheet No.**	2	**of**
Location:	Branford, CT – Long Island Sound	**Job No.**	200242	

Subject:	SMB Hindcast Model with Shallow	**Made By**	Roberge	**Date** 11/26/2002
	Water Correction – 50 Yr Wind / 50 Yr Depth	**Chkd. By**		**Date**

Constants

		Units	
Gravity, g	9.81	m/s^2	
Surface Wind, Us	90.0	mi/hr	Ref: Handbook of Ocean and Underwater Engineering
	40.2	m/s	Myers, Holm, McAllister, ed, McGraw-Hill, 1969, p.8-5
Wind Stress Factor, U$_A$	66.8	m/s	$U_A = 0.71 U_S^{1.23}$

Variables

	Units	Reach #1	Reach #2
Wind Direction		South	SW
Fetch Distance, F	n.mi	20.4	54.0
	m	37780.8	100008.0
Average Water Depth,	ft	85.0	79.0
	m	25.9	24.1

Calculations

	Units	Reach #1	Reach #2
Wave Height, H	m	5.4	6.7
	ft	17.8	22.0

$$H = \frac{.283 U_A^{\,2}}{g} \tanh\left[.530\left(\frac{gd}{U_A^{\,2}}\right)^{3/4} \right] \tanh\left[\frac{.00565\left(\frac{gF}{U_A^{\,2}}\right)^{1/2}}{\tanh\left[.530\left(\frac{gd}{U_A^{\,2}}\right)^{3/4} \right]} \right]$$

Wave Period, T	Units	Reach #1	Reach #2
	sec	7.6	9.6

$$T = \frac{7.54 U_A}{g} \tanh\left[.833\left(\frac{gd}{U_A^{\,2}}\right)^{3/8} \right] \tanh\left[\frac{.0379\left(\frac{gF}{U_A^{\,2}}\right)^{1/3}}{\tanh\left[.833\left(\frac{gd}{U_A^{\,2}}\right)^{3/8} \right]} \right]$$

Duration, t	Units	Reach #1	Reach #2
	hrs	2.5	4.7

$$t = 8.93 \times 10^{-1}\left(\frac{F^2}{U_A}\right)^{1/3}$$

Rev. No.	
Made By	**Date**

JOHN C. ROBERGE, P.E., LLC

Project:	Islander East Pipeline Construction		**Sheet No.**	3	**of**	
Location:	Branford, CT - Long Island Sound		**Job No.**	200242		
Subject:	SMB Hindcast Model with Shallow		**Made By**	Roberge	**Date**	11/26/2002
	Water Correction - 2 Yr Wind / 2 Yr Depth		**Chkd. By**		**Date**	

Constants

		Units	
Gravity, g	9.81	m/s^2	
Surface Wind, Us	50.0	mi/hr	Ref: Handbook of Ocean and Underwater Engineering
	22.4	m/s	Myers, Holm, McAllister, ed, McGraw-Hill, 1969, p.8-5
Wind Stress Factor, Ua	32.4	m/s	$U_A = 0.71 U_S^{1.23}$

Variables

	Units	Reach #1	Reach #2
Wind Direction		South	SW
Fetch Distance, F	n.mi	20.4	54.0
	m	37780.8	100008.0
Average Water Depth,	ft	82.0	77.0
	m	25.0	23.5

Calculations

	Units	Reach #1	Reach #2
Wave Height, H	m	2.9	3.9
	ft	9.4	12.9

$$H = \frac{.283 U_A^2}{g} \tanh\left[.530\left(\frac{gd}{U_A^2}\right)^{3/4}\right] \tanh\left[\frac{.00565\left(\frac{gF}{U_A^2}\right)^{1/2}}{\tanh\left[.530\left(\frac{gd}{U_A^2}\right)^{3/4}\right]}\right]$$

	Units	Reach #1	Reach #2
Wave Period, T	sec	6.0	7.5

$$T = \frac{7.54 U_A}{g} \tanh\left[.833\left(\frac{gd}{U_A^2}\right)^{3/8}\right] \tanh\left[\frac{.0379\left(\frac{gF}{U_A^2}\right)^{1/3}}{\tanh\left[.833\left(\frac{gd}{U_A^2}\right)^{3/8}\right]}\right]$$

	Units	Reach #1	Reach #2
Duration, t	hrs	3.2	6.0

$$t = 8.93 \times 10^{-1}\left(\frac{F^2}{U_A}\right)^{1/3}$$

Rev. No.	
Made By	**Date**

JOHN C. ROBERGE, P.E., LLC

Project:	Islander East Pipeline Construction	**Sheet No.**	1	**of**	
		Job No.	200242		
Subject:	Erosion Potential of Dredge Mounds	**Made By**	Roberge	**Date**	12/05/02
	MP 10.95 - 100 Yr Return	**Chkd. By**		**Date**	

MAXIMUM WATER PARTICLE VELOCITIES BENEATH DESIGN WAVE
MP 10.95 - Water Depth = 13 ft (MLW) - Breaking Conditions (Depth Limited)
100 Yr Return Period

SITE CONDITIONS :

H wave =	16.6	ft	
T wave =	10.0	sec	
L wave =	199.0	ft	(See NOTE)
d, depth =	13.0	ft	

Depth, Ft	Umax, Ft/sec
13.0	12.37
12.5	12.37
12.0	12.38
11.5	12.39
11.0	12.40
10.5	12.41
10.0	12.43
9.5	12.45
9.0	12.47
8.0	12.53
7.0	12.60
6.0	12.68
5.0	12.77
4.0	12.88
3.0	13.00
2.0	13.13
1.0	13.27
0.0	13.43

Maximum Water Particle Velocities will occur in coincidence with the passing of the wave crest and / or trough. Design must consider the relative direction of the water particle motion.

NOTE : d / L_o { For Design Conditions} = 0.0254

Wavelength at Site, L, can be determined from Tables Showing Functions of d / L for Increments of d / L_o.

Rev. No.	
Made By	**Date**

File Ref.: orbvel

JOHN C. ROBERGE, P.E., LLC

Project:	Islander East Pipeline Construction	**Sheet No.**	1	**of**
		Job No.	200242	
Subject:	Erosion Potential of Dredge Mounds	**Made By**	Roberge	**Date** 12/05/02
	MP 11.5 - 100 Yr Return	**Chkd. By**		**Date**

MAXIMUM WATER PARTICLE VELOCITIES BENEATH DESIGN WAVE

MP 11.5 - Water Depth = 16.7 ft (MLW) - Breaking Conditions (Depth Limited)
100 Yr Return Period

SITE CONDITIONS :

H wave =	21.4	ft
T wave =	10.0	sec
L wave =	224.0	ft (See NOTE)
d, depth =	16.7	ft

Depth, Ft	Umax, Ft/sec
16.7	13.84
16.0	13.84
15.5	13.84
15.0	13.85
14.5	13.86
14.0	13.88
13.5	13.89
13.0	13.91
12.0	13.96
10.0	14.08
8.0	14.25
6.0	14.46
5.0	14.59
4.0	14.72
3.0	14.87
2.0	15.03
1.0	15.20
0.0	15.38

Maximum Water Particle Velocities will occur in coincidence with the passing
of the wave crest and / or trough. Design must consider the relative direction
of the water particle motion.

NOTE : d / Lo { For Design Conditions} = 0.0326

Wavelength at Site, L, can be determined from Tables
Showing Functions of d / L for Increments of d /Lo.

Rev. No.		**File Ref.: orbvel**
Made By	**Date**	

JOHN C. ROBERGE, P.E., LLC

MAXIMUM WATER PARTICLE VELOCITIES BENEATH DESIGN WAVE
MP 12.0 - Water Depth = 21 ft (MLW) - Non-Breaking Conditions
100 Yr Return Period

SITE CONDITIONS :

H wave =	24.5	ft
T wave =	10.0	sec
L wave =	248.8	ft (See NOTE)
d, depth =	21.0	ft

Depth, Ft	Umax, Ft/sec
21.0	13.86
20.0	13.86
18.0	13.90
16.0	13.97
14.0	14.08
12.0	14.22
11.0	14.30
10.0	14.40
9.0	14.50
8.0	14.61
7.0	14.73
6.0	14.87
5.0	15.01
4.0	15.16
3.0	15.32
2.0	15.49
1.0	15.66
0.0	15.85

Maximum Water Particle Velocities will occur in coincidence with the passing of the wave crest and / or trough. Design must consider the relative direction of the water particle motion.

NOTE : d / L_o { For Design Conditions} =   0.0410

Wavelength at Site, L, can be determined from Tables Showing Functions of d / L for Increments of d / L_o.

File Ref.: orbvel

Rev. No.			
Made By		**Date**	

JOHN C. ROBERGE, P.E., LLC

Project:	Islander East Pipeline Construction	**Sheet No.**	1	**of**		
		Job No.	200242			
Subject:	Erosion Potential of Dredge Mounds	**Made By**	Roberge	**Date**	12/05/02	
	MP 10.95 - 50 Yr Return	**Chkd. By**		**Date**		

MAXIMUM WATER PARTICLE VELOCITIES BENEATH DESIGN WAVE
MP 10.95 - Water Depth = 13 ft (MLW) - Breaking Conditions (Depth Limited)
50 Yr Return Period

SITE CONDITIONS :

H wave =	16.6	ft
T wave =	9.6	sec
L wave =	191.0	ft (See NOTE)
d, depth =	13.0	ft

Depth, Ft	Umax, Ft/sec
13.0	12.29
12.5	12.29
12.0	12.30
11.5	12.31
11.0	12.32
10.5	12.33
10.0	12.35
9.5	12.37
9.0	12.40
8.0	12.46
7.0	12.53
6.0	12.62
5.0	12.72
4.0	12.83
3.0	12.96
2.0	13.11
1.0	13.26
0.0	13.43

Maximum Water Particle Velocities will occur in coincidence with the passing of the wave crest and / or trough. Design must consider the relative direction of the water particle motion.

NOTE : d / L_o { For Design Conditions} = 0.0276

Wavelength at Site, L, can be determined from Tables
Showing Functions of d / L for Increments of d / L_o.

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Made By	**Date**	

JOHN C. ROBERGE, P.E., LLC

MAXIMUM WATER PARTICLE VELOCITIES BENEATH DESIGN WAVE
MP 10.95 - Water Depth = 13 ft (MLW) - Non-Breaking Conditions
2 Yr Return Period

SITE CONDITIONS :   H wave = 12.9 ft
                    T wave = 7.5 sec
                    L wave = 146.0 ft   (See NOTE)
                    d, depth = 13.0 ft

Depth, Ft	Umax, Ft/sec
13.0	9.19
12.5	9.19
12.0	9.20
11.5	9.21
11.0	9.23
10.5	9.25
10.0	9.27
9.5	9.30
9.0	9.33
8.0	9.41
7.0	9.50
6.0	9.61
5.0	9.74
4.0	9.89
3.0	10.06
2.0	10.24
1.0	10.45
0.0	10.67

Maximum Water Particle Velocities will occur in coincidence with the passing
of the wave crest and / or trough. Design must consider the relative direction
of the water particle motion.

NOTE : d / L_o { For Design Conditions} =   0.0451

Wavelength at Site, L, can be determined from Tables
Showing Functions of d / L for Increments of d / L_o.

Rev. No.	File Ref.: orbvel
Made By	**Date**

JOHN C. ROBERGE, P.E., LLC

Project: Islander East Pipeline Construction   **Sheet No.** 1   **of**

                                Job No. 200242

Subject: Erosion Potential of Dredge Mounds   **Made By** Roberge   **Date**   12/05/02

           MP 11.5 - 2 Yr Return   **Chkd. By**   **Date**

MAXIMUM WATER PARTICLE VELOCITIES BENEATH DESIGN WAVE

MP 11.5 - Water Depth = 16.7 ft (MLW) - Non-Breaking Conditions

2 Yr Return Period

SITE CONDITIONS :

H wave =	12.9	ft
T wave =	7.5	sec
L wave =	163.0	ft (See NOTE)
d, depth =	16.7	ft

Depth, Ft	Umax, Ft/sec
16.7	7.87
16.0	7.87
15.5	7.88
15.0	7.89
14.5	7.90
14.0	7.91
13.5	7.93
13.0	7.95
12.0	8.00
10.0	8.13
8.0	8.32
6.0	8.55
5.0	8.68
4.0	8.83
3.0	8.99
2.0	9.17
1.0	9.35
0.0	9.56

Maximum Water Particle Velocities will occur in coincidence with the passing of the wave crest and / or trough. Design must consider the relative direction of the water particle motion.

NOTE : d / L_o { For Design Conditions} =   0.0580

Wavelength at Site, L, can be determined from Tables Showing Functions of d / L for Increments of d / L_o.

File Ref.: orbvel

JOHN C. ROBERGE, P.E., LLC

MAXIMUM WATER PARTICLE VELOCITIES BENEATH DESIGN WAVE

MP 12.0 - Water Depth = 21 ft (MLW) - Non-Breaking Conditions
2 Yr Return Period

SITE CONDITIONS :

H wave =	12.9	ft	
T wave =	7.5	sec	
L wave =	180.0	ft	(See NOTE)
d, depth =	21.0	ft	

Depth, Ft	Umax, Ft/sec
21.0	6.76
20.0	6.76
18.0	6.79
16.0	6.86
14.0	6.96
12.0	7.09
11.0	7.17
10.0	7.26
9.0	7.36
8.0	7.46
7.0	7.58
6.0	7.70
5.0	7.84
4.0	7.98
3.0	8.13
2.0	8.30
1.0	8.47
0.0	8.65

Maximum Water Particle Velocities will occur in coincidence with the passing of the wave crest and / or trough. Design must consider the relative direction of the water particle motion.

NOTE :   d / Lo { For Design Conditions} =   0.0729

Wavelength at Site, L, can be determined from Tables Showing Functions of d / L for Increments of d /Lo.

Rev. No.		File Ref.: orbvel
Made By	Date	

JOHN C. ROBERGE, P.E., LLC

Project:	**ISLANDER EAST PIPELINE**	Sheet No.	**1** of	
		Job No.	Branford 200242	
Subject:	**Construction Methods Assessment**	Made By:	Roberge	Date
	Sediment Dispersion Simulation	Chkd. By:		Date

PIPELINE STATION:		MP 11.5	Flood Flow Condition		R = 1,684 g/s			Case 10

TURBIDITY PLUME CENTERLINE CONCENTRATION, mg/liter

Depth, m	Current m/s	Distance From Trenching Operation, m							
		5	20	80	100	200	300	400	1000
Flood 5.10	0.57	527	132	33	26	13	9	7	3
Ebb 7.10	0.72	299	75	19	15	7	5	4	1
Average 6.10	0.66	380	95	24	19	10	6	5	2

Trenching Sediment Release Rate, R:	1684 g/s	Current Angle:	265

Basin Construction and trenching MP 10.9 to MP 12.0 – Islander East Pipeline – Thimble Islands, CT

Trench excavated by Bucket Dredge, per Islander East documents. Excavation of 272 CF / LF of trench (or about 10CY/LF). Anticipate a bucket of about 10 CY capacity. Estimate cycle speed for bucket will be about 60 sec at this shallow site. The trench advance rate will be approximately 1.0 ft/min. Considering that anchors / spud repositioning every 120 LF of trench (est. length of work barge) and that repositioning will require approx. 45 minutes - Production will be approximately 44 LF/hr. Possible that the trench will advance 270 LF during each Flood and Ebb tidal cycle.

Deposition potential was represented by the extent of the lines of constant C assuming that all of the suspended material could settle at that position. Thickness of the settled material is directly related to plume concentration.

$$\text{Thickness (cm)} = \frac{C\ (mg/L) \times Depth\ (m)}{Bulk\ Density\ (10000)}$$

Bulk Density (g/cc) : 1.5

Deposited Sediment Layer Thickness, cm

Plume	Distance From Trenching Operation, m							
	5	20	80	100	200	300	400	1000
Flood	0.25	0.04	0.01	0.01	0.01	0.00	0.00	0.00
Ebb	0.14	0.04	0.01	0.01	0.00	0.00	0.00	0.00

Rev. No.
Made By   Date

JOHN C. ROBERGE, P.E., LLC

Project:	**ISLANDER EAST PIPELINE**	**Sheet No.**	1 of
		Job No.	Branford 200242
Subject:	**Construction Methods Assessment**	**Made By:**	Roberge Date
	Sediment Dispersion Simulation	**Chkd. By:**	Date

| PIPELINE STATION: | | MP 11.5 | Flood Flow Condition | | | R = 445 g/s | | | Case 11 |

TURBIDITY PLUME CENTERLINE CONCENTRATION, mg/liter

Depth, m	Current m/s	Distance From Trenching Operation, m							
		5	20	80	100	200	300	400	1000
Flood 5.10	0.57	139	35	9	7	3	2	2	1
Ebb 7.10	0.72	79	20	5	4	2	1	1	0
Average 6.10	0.66	100	25	6	5	3	2	1	1

Trenching Sediment Release Rate, R:	445	g/s	Current Angle:	265

<u>Basin Construction and trenching MP 10.9 to MP 12.0 – Islander East Pipeline – Thimble Islands, CT</u>

Trench excavated by Bucket Dredge, per Islander East documents. Excavation of 272 CF / LF of trench (or about 10CY/LF). Anticipate a bucket of about 10 CY capacity. Estimate cycle speed for bucket will be about 60 sec at this shallow site. The trench advance rate will be approximately 1.0 ft/min. Considering that anchors / spud repositioning every 120 LF of trench (est. length of work barge) and that repositioning will require approx. 45 minutes - Production will be approximately 44 LF/hr. Possible that the trench will advance 270 LF during each Flood and Ebb tidal cycle.

Deposition potential was represented by the extent of the lines of constant C assuming that all of the suspended material could settle at that position. Thickness of the settled material is directly related to plume concentration.

$$\text{Thickness (cm)} = \frac{C \text{ (mg/L)} \times \text{Depth (m)}}{\text{Bulk Density (10000)}}$$

Bulk Density (g/cc): 1.5

Deposited Sediment Layer Thickness, cm

Plume	Distance From Trenching Operation, m							
	5	20	80	100	200	300	400	1000
Flood	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Ebb	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00

Rev. No.

Made By   **Date**